

Human Factors Process Task Analysis

Liquid Oxygen Pump
Acceptance Test Procedure
at the Advanced Technology Development Center

Engineering Development Contract
September 30, 2002

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Scope of Task Analysis Effort

June – September 2002

Task Order 5SMA768

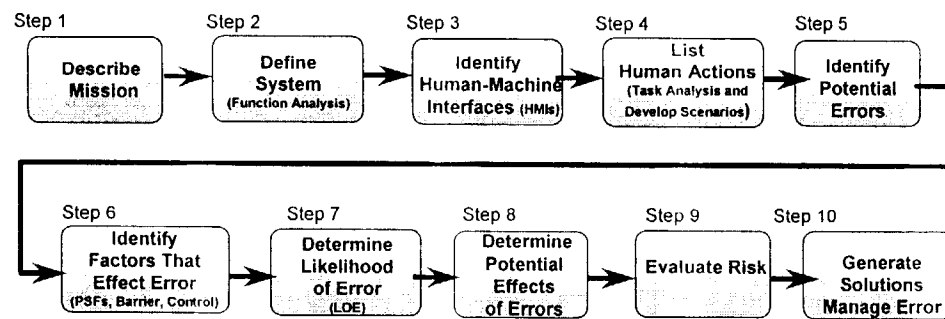
Funding provided through collaborative effort
between Ames Research Center, Code M/HQ, and
IES

Perform Human Factors Process Failure Modes and
Effects Analysis (HF PFMEA) of OTM-2002,
LOX Pump Acceptance Test Procedure for ATDC



Mission Success Starts With Safety

10 Basic Steps in HF PFMEA



Methodology

Reviewed system drawings, specifications and standards, project documentation

Evaluated draft test procedure OTM-2002

Consideration of risks

Requirement, potential human error, and analysis of the error

Six Major Categories Evaluated

Personnel Certification

Test Procedure Format

Test Procedure Safety Controls

Test Article Data

Instrumentation

Voice Communication

Topics Addressed

Requirement

Potential Human Error

Performance-Shaping Factors

Potential Effects of the Error

Barriers and Controls

Risk Priority Number

Recommended Actions

Performance Shaping Factors

Internal – within the worker; human attributes typically related to physical or mental characteristics

examples – skills , knowledge, strength, stress, fatigue, motivation

External – factors outside the worker that affect human performance

examples – inadequate tool design, environmental factors, incomplete documentation, insufficient training

Potential Effects of the Error

Injury to personnel

Equipment damage

Test delay

Repeat test

Invalid data

System activation delay

Unknown configuration

Barriers and Controls

Barriers – prevent the error from occurring

examples – design safeguards, physical restraints

Controls – prevent the effect of the error from occurring

examples – training, on-the-job experience, documentation, briefings, communication

Risk Priority Numbers (RPN's)

Used a 10-point scale

Severity – assess the magnitude of the immediate effect of the error

Detection – assess the effectiveness of the controls, thus impacting the effects of the error

Likelihood – assess the occurrence of the error

Risk Priority Number = $S \times D \times L$

Highest RPN's need most attention

Recommended actions

Summary of Findings

Report

HF PFMEA Table

Technology barriers and challenges to
performing task analyses

Lessons learned

Conclusion and recommendations

KSC-YA-6040

**HUMAN FACTORS PROCESS TASK ANALYSIS
LIQUID OXYGEN PUMP ACCEPTANCE TEST
PROCEDURE FOR THE ADVANCED TECHNOLOGY
DEVELOPMENT CENTER**

September 28, 2002

**SPACEPORT ENGINEERING
AND TECHNOLOGY DIRECTORATE**

National Aeronautics and
Space Administration

John F. Kennedy Space Center



**HUMAN FACTORS PROCESS TASK ANALYSIS
LIQUID OXYGEN PUMP ACCEPTANCE TEST
PROCEDURE FOR THE ADVANCED TECHNOLOGY
DEVELOPMENT CENTER**

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September 28, 2002

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EXECUTIVE SUMMARY

A process task analysis effort was undertaken by Dynacs Inc. commencing in June 2002 under contract from NASA YA-D6. Funding was provided through NASA's Ames Research Center (ARC), Code M/HQ, and Industrial Engineering and Safety (IES). The John F. Kennedy Space Center (KSC) Engineering Development Contract (EDC) Task Order was 5SMA768.

The scope of the effort was to conduct a Human Factors Process Failure Modes and Effects Analysis (HF PFMEA) of a hazardous activity and provide recommendations to eliminate or reduce the effects of errors caused by human factors. The Liquid Oxygen (LOX) Pump Acceptance Test Procedure (ATP) was selected for this analysis.

The HF PFMEA table (see appendix A) provides an analysis of six major categories evaluated for this study. These categories include Personnel Certification, Test Procedure Format, Test Procedure Safety Controls, Test Article Data, Instrumentation, and Voice Communication.

For each specific requirement listed in appendix A, the following topics were addressed: Requirement, Potential Human Error, Performance-Shaping Factors, Potential Effects of the Error, Barriers and Controls, Risk Priority Numbers, and Recommended Actions.

This report summarizes findings and gives recommendations as determined by the data contained in appendix A. It also includes a discussion of technology barriers and challenges to performing task analyses, as well as lessons learned.

The HF PFMEA table in appendix A recommends the use of accepted and required safety criteria in order to reduce the risk of human error. The items with the highest risk priority numbers should receive the greatest amount of consideration. Implementation of the recommendations will result in a safer operation for all personnel.

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1. INTRODUCTION

A process task analysis effort was undertaken by Dynacs Inc. commencing in June 2002 under contract from NASA YA-D6. Funding was provided through NASA's Ames Research Center (ARC), Code M/HQ, and Industrial Engineering and Safety (IES). The John F. Kennedy Space Center (KSC) Engineering Development Contract (EDC) Task Order was 5SMA768.

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The HF PFMEA table (see appendix A) provides an analysis of six major categories evaluated for this study. These categories include the following:

- a. Personnel Certification
- b. Test Procedure Format
- c. Test Procedure Safety Controls
- d. Test Article Data
- e. Instrumentation
- f. Voice Communication

For each specific requirement listed in appendix A, the following topics were addressed:

- a. Requirement
- b. Potential Human Error
- c. Performance-Shaping Factors
- d. Potential Effects of the Error
- e. Barriers and Controls
- f. Risk Priority Numbers
- g. Recommended Actions

This report summarizes findings and gives recommendations as determined by the data contained in appendix A. It also includes a discussion of technology barriers and challenges to performing task analyses, as well as lessons learned.

2. BACKGROUND

Two new candidate pumps are scheduled to be tested during fiscal year 2003 as potential spares for use in the LOX loading operations at Launch Complex 39. The pumps were acquired from Borg Warner International Products and are being provided by NASA PH for testing at the Advanced Technology Development Center (ATDC) located at Complex 20 on Cape Canaveral Air Force Station. The pumps were designed and manufactured to be as identical as possible to the current pumps.

Initial testing of the two pumps will be conducted using the water flow loop at the Launch Equipment Test Facility (LETf) located in the Industrial Area of Kennedy Space Center. Subsequent testing using liquid nitrogen (LN₂) and LOX will be performed at the ATDC.

Systems Assurance Analyses (SAA's) that will include hardware FMEA's for the many different facility systems comprising the ATDC are being developed separately. The focus of this study was limited to the conduct of a HF PFMEA for the LOX pump testing at the ATDC.

3. APPROACH

This HF PFMEA consisted of reviewing system design drawings, applicable referenced specifications and standards, the test procedure, and draft versions of several documents being developed specifically for the ATDC.

The project-specific documents include the Liquid Oxygen Pump Acceptance Test Requirements Document (85K01304, 90% draft dated May 8, 2002), the Liquid Oxygen Pump Acceptance Test Plan (KSC-YA-5732, 30% draft version, dated June 19, 2002), and Liquid Oxygen Pump Cryogenic Test Procedure (OTM 2002, draft version, dated February 22, 2002), the Safety and Mission Assurance Plan for ATDC (85K01050, draft version, dated September 2002), and the Risk Management Plan for ATDC (85K01010, draft version, dated May 11, 2001). Operations and Maintenance Instruction (OMI) G2115 M01, LOX Pump Test, was also reviewed.

NSS 1740.15 was found to be the most comprehensive source of information and guidelines applicable to risks associated with the planned LOX pump testing activity. KHB 1710.2 also provides guidance for hazardous operations.

4. DISCUSSION

Initial testing of the LOX pumps at the new ATDC facility will be conducted using LN₂. This will provide operators familiarization with the ATDC facility, ground support equipment (GSE) systems, and the test article itself. It will allow for facility design or testing problems to be ad-

dressed prior to entering the hazardous LOX phase of testing. At this time, additional test procedure modifications related to human factors could also be considered. They would be presented in accordance with severity of the associated risks.

It is important to note that the test procedure evaluated for this study is in very early draft form and that ongoing facility design will result in any number of changes to the procedure. The information presented in this report provides an evaluation of applicable human factor conditions that warrant attention due to the hazardous nature of cryogenic operations. In addition, the results describe typical human factor considerations that can be applied to other test operations.

Appendix A outlines six major areas judged applicable for evaluation and the following paragraphs summarize significant points.

4.1 PERSONNEL CERTIFICATION

Personnel certifications related to cryogenic operations, and specifically LOX operations, have not been instituted for the contractor (EDC) employees who will be performing the operations. Cryogenic Safety training is essential for all employees involved in LOX operations. Certifications should be considered as well.

Currently, the Safety and Mission Assurance Plan for ATDC states that, as a minimum, all employees working with cryogenics must have attended the Cryogenics Safety and High Pressure Gas Safety courses. Records for EDC personnel indicate that many employees have attended the subject training. Attendance in most cases, however, was many years ago. Since the courses are set up as one-time only, refresher training is not routinely scheduled.

In addition, NSS 1740.15 paragraph 103, Personnel Training, states that personnel be certified in accordance with NHB 1700.1 and they shall be qualified to respond properly to all foreseeable failure modes. They must be trained in the selection of equipment for handling LOX in the procedures for handling spills and leaks and disposing of oxygen.

The experience base on the EDC includes significant test operations using both liquid nitrogen and liquid hydrogen. The additional hazards associated with liquid oxygen need to be identified and presented to operations personnel in a formal manner and controlled to reduce risk of accident. Safeguards must be established and enforced in order to minimize the occurrence and effect of an error.

NASA personnel involved in cryogenic operations also require safety training and certification in accordance with KHB 3410.1. The recommendations for EDC personnel should also be applied to NASA.

4.2 TEST PROCEDURE FORMAT

The acceptance test procedure is designated as an Operations Technical Manual (OTM). The Objective section of the OTM states, "This procedure is a subtask procedure, which provides detailed direction for operating facility equipment in support of a specific test or system check."

Since this test is a category 1 hazardous operation, as defined in KHB 1710.2, a Safety-approved format such as the OMI should be employed. Utilizing the OMI format would help to standardize the hazardous procedure requirements.

4.3 TEST PROCEDURE SAFETY CONTROLS

Emergency Procedures, included as Appendix Z to OTM 2002, are separated into eight different types of emergencies. This structure could lead to confusion and mishandling of an emergency. In any event, Emergency Procedures must be emphasized at every pretest briefing.

Weather restrictions, clear areas, controlled access areas, and fire services notification also require further attention. Multiple Safety offices will perform thorough evaluations and approval of the procedure.

4.4 TEST ARTICLE DATA

NSS 1740.15 states, "Materials procured for use in oxygen systems require a material certification from the manufacturer." Originals or copies of this information need to be provided to the contractor Quality Assurance organization for inclusion in the acceptance data package. The materials must be compatible with oxygen and include certification from the vendor.

Pump manufacturer data must demonstrate the pump meets all the safety requirements for oxygen use. Material certifications must be obtained for all materials that will be exposed to oxygen.

Cleaning records must be obtained and maintained for the test article and the gaseous and cryogenic portions of the system. Originals or copies of this information should be provided to the contractor Quality Assurance organization for inclusion in the acceptance data package.

A contaminated system will cause personnel to be exposed to risks resulting from unknown configuration. In the event that a material, design, or handling problem leads to a mishap, the results could be catastrophic.

4.5 INSTRUMENTATION

Accurate and verified calibration of instrumentation used in test operations is critical to ensure successful test operations. Selection of the correct instrumentation is also essential to obtain informative results.

Definition of instrumentation requirements is worked in conjunction with development of test requirements. The methods and practices used in the implementation of instrumentation requirements must be established, documented, and followed in order to ensure reliable test results. Consideration must be given to equipment calibration, accuracy, and range, frequency response, proper location in the system, and end-to-end verification to ensure the data gathered and recorded are consistent with the desired results.

Also, sufficient time must be allocated to prepare the necessary instrumentation as previously stated to support all phases of the testing process.

4.6 VOICE COMMUNICATION

Voice communications requirements are established in both the facility setup and in the test operations documentation. Preliminary checkout and functional verification of the systems and equipment must be performed to ensure proper operation. Specifics related to the test operations, such as hazards, test objectives, and communication protocols, are discussed at pretest briefings. All personnel are responsible for understanding communication requirements and notifying the test conductor of any equipment problems.

The 85K01050, ATDC Safety and Mission Assurance Plan, specifies the overall safety requirements for hazardous operations at ATDC. It is recommended that the applicable information also be specifically addressed in the test procedure, since personnel conducting test operations will not likely have the S&MA Plan available.

5. TECHNOLOGY BARRIERS AND CHALLENGES TO PERFORMING TASK ANALYSES

Some technology barriers inhibiting the ability to perform task analyses do exist. One area currently being addressed is the creation of software tools that will facilitate the performance of task analyses. Another barrier is ready availability of necessary data for input into the tools. A system that accepts early definition of data requirements for task analyses would be beneficial.

Challenges to performing task analyses include the amount of labor required and the associated costs. Other challenges are the need to ensure the analyses provide effective results that help to reduce risks related to human factors and the drive to expand awareness, understanding, and appreciation of the benefits of task analyses.

As the field of human factors expands into more project areas, the knowledge resulting from task analyses activities will become more valued. A good way to accomplish this expansion is to develop working relationships with the design and operations organizations and communicate the goals, methods, and benefits of task analyses. Finally, consideration of the findings and recommendations is essential to realization of the results and benefits of task analyses.

6. LESSONS LEARNED

A primary lesson learned is an increased awareness of the value in performing task analyses. The concentration of experience within the discipline of human factors must be expanded further into the design and assurance activities for new projects. Consideration of human factors on existing operations is equally as important, especially for critical, hazardous, or complex operations.

Early integration of the task analysis process into design or operations activities would minimize cost and aid in acceptance of task analysis recommendations. In today's budget environment, resource and funding availability is an area that also requires attention in order to conduct task analyses with beneficial results. Workforce awareness, knowledge, and appreciation of task analyses and their benefits will continue to increase as more task analyses are performed and utilized.

Quantifying the benefits of task analyses results is difficult during the design and early operational stages, as the availability of historical process data does not already exist. For established processes, however, analytical data can be collected to quantify the results or effects of process task analysis recommendations.

7. CONCLUSION AND RECOMMENDATIONS

Conducting process task analyses, particularly on hazardous operations, is a worthwhile, cost-effective, beneficial activity. Awareness of the human element and its potential effect on an operation must be placed at the forefront of operations. Task analyses provide a means to formalize the subject of human factors and provide documentation and mitigation of potential human factor issues.

The HF PFMEA table recommends the use of accepted and required safety criteria in order to reduce the risk of human error. The items with the highest risk priority numbers should receive the greatest amount of consideration. Implementation of the recommendations will result in a safer operation for the benefit of all personnel.

APPENDIX A

HUMAN FACTORS PROCESS FAILURE MODES AND EFFECTS
ANALYSIS (HF PFMEA)
LOX PUMP ACCEPTANCE TEST PROCEDURE

HUMAN FACTORS PROCESS FAILURE MODES AND EFFECTS ANALYSIS (HF PFMEA)
LOX PUMP ACCEPTANCE TEST PROCEDURE

	Requirement	Potential Human Error	Performance-Shaping Factor	Potential Effects of Error	Barriers and Controls	S	D	L	RPN	Recommended Actions
1	Personnel Certification									
1.1	Engineering Development Contract employee certification program	Improper safety precautions; judgement error	LTA recent knowledge	Mishap; Emergency handling	Adequate training for using LOX; on-the-job experience	10	10	8	800	Review and update EDC safety training program for cryogenics per KHB 3410.1
1.2	NASA employee certification requirements	Improper safety precautions; judgement error	LTA recent knowledge	Mishap; emergency handling	Adequate training for using LOX; on-the-job experience	10	10	8	800	Review and update NASA safety training program for cryogenics per KHB 3410.1
1.3	LOX-specific training	Improper safety precautions; judgement error	LTA training requirements for LOX testing	LOX-related emergency	Adequate training for using LOX; on-the-job experience	10	10	8	800	Establish and administer LOX-specific training and certification
1.4	Experience levels	Improper safety precautions; judgement error	Unfamiliar with LOX hazards	Mishap; injury; hardware damage	Adequate training for using LOX; on-the-job experience	10	10	6	600	Designate experienced cryogenics lead
1.5	System familiarity	Improper safety precautions; judgement error	New system; LTA documentation	Mishap; injury; hardware damage	Adequate training for using LOX; on-the-job experience	10	10	6	600	Provide hands-on system experience; document system-unique information

	Requirement	Potential Human Error	Performance-Shaping Factor	Potential Effects of Error	Barriers and Controls	S	D	L	RPN	Recommended Actions
1.6	Defined test team	Improper safety precautions; judgement error	LTA training background	Operator not certified	Adequate training for using LOX; on-the-job experience	5	5	5	125	Establish proper mix of test personnel; designate roles and responsibilities; conduct dry run operations
2	Test Procedure Format									
2.1	OTM vs. OMI format	Informal test discipline	LTA instructions	Mishap; test delay; test invalidation	OMI format required per KHB 1710.2	8	8	7	448	Revise test procedure to be an OMI instead of the less formal OTM
2.2	Cautions, warnings, and notes	Overlook caution, warning, or note	LTA instructions	Mishap; missed data	OMI format required per KHB 1710.2	10	6	6	360	Make cautions, warnings, and notes more noticeable, as is the case in OMI G2115, LOX Pump Test
2.3	Commingling LOX and LN ₂ steps	Misread test instruction step	Similarity of wording but significantly different safety criteria	Mishap; missed data	None	9	9	8	648	Make separate test sequences for LN ₂ and LOX testing
2.4	"Not performed" steps	Perform and buy off step that should have been skipped	"Not performed" criteria not well defined	Mishap; incorrect step performed; test invalidation; test repeat; schedule slips	Format per KHB 1710.2	9	9	8	648	Include criteria prior to "Not Performed" steps; include buy-off for "NP"
2.5	Clarity of wording of test instruction steps	Misunderstood test instruction step	LTA test instructions; assumption of operator knowledge	Mishap; incorrect step performed; test invalidation; test repeat; schedule slips	None	9	9	8	648	Revise steps to clarify wording and eliminate assumptions

	Requirement	Potential Human Error	Performance-Shaping Factor	Potential Effects of Error	Barriers and Controls	S	D	L	RPN	Recommended Actions
2.6	Technician and Quality buy-off steps	Missed verification	LTA documentation; distracted; multiple events occurring at	Inaccurate data; unknown configuration	Format per KHB 1710.2	8	8	5	320	Revise test procedure to include necessary technician and quality buy-offs
2.7	Authorizing documentation	Misunderstood instruction	Clarity of authorizing documentation; documentation missing	Test steps not performed as needed	EDC Work Control system	5	5	3	75	Ensure authorizing documentation prepared, distributed, and understood; address questions prior to test operations
2.8	Pretest and Post-test briefings	Information not received or understood	Absent from briefing; distracted	Judgement errors; mishap	Required per test procedure	8	5	5	200	Ensure attendance and address questions
2.9	Shutdown and restart operations	Performing action without documented test procedure steps	LTA documentation; information not distributed	Improper shutdown; unknown configuration	Approved procedure deviations	9	2	8	144	Establish method to document shutdown and restart operations; communicate at pretest briefings
3	Test Procedure Safety Controls									
3.1	Clear areas/controlled areas	Not established or not properly controlled	LTA instructions or enforcement	Mishap; injury	Safety tape; camera monitoring	7	2	2	28	Emphasize safety controls during pretest briefings
3.2	Essential personnel	Unauthorized personnel in area	LTA instructions or enforcement	Mishap; injury	Access badge checks; camera monitoring	4	2	2	16	Enforce personnel limits approved in test procedure
3.3	Weather restrictions	Failure to heed warnings; failure to hear warnings	Speakers missing or not functioning; excessive noise masking announcement; wet structures	Weather-enhanced mishap; lightning strikes	Public Address announcement	9	2	4	72	Verify PA system operation prior to test commencement; emphasize weather restrictions during pretest briefings

	Requirement	Potential Human Error	Performance-Shaping Factor	Potential Effects of Error	Barriers and Controls	S	D	L	RPN	Recommended Actions
3.4	Emergency shut-down	Panic; mishandled emergency	LTA instructions; unfamiliar with instructions	Increased risk or damage	Test procedure appendix Z; pretest briefings; communication system; trained emergency personnel	10	5	8	400	Emphasize emergency procedures during pretest briefings; dry run emergency procedures
3.5	Equipment calibration	Failure to check calibration status; failure to maintain current calibration	LTA instructions; schedule pressures	Inaccurate data; configuration unknown; dangerous conditions not identified; test delay		10	2	3	60	Document calibration requirements on work instructions; include verification requirement in test procedure (Preoperations Setup Instructions)
3.6	Fire services notification	Fail to notify	LTA instructions	Fire services unaware of hazardous operations; understaffed for support	Preoperation setup instructions; responsible safety person	10	1	2	20	Add test procedure steps to accomplish notification; buy off when complete
3.7	Test configuration control	Operating in unknown configuration	Inadequate documentation	Mishap; test invalidation; injury; hardware damage	Verification of test configuration; controlled areas; essential personnel	10	4	4	160	Establish and maintain configuration control at all times; document all changes on test deviation; verify new configuration

	Requirement	Potential Human Error	Performance-Shaping Factor	Potential Effects of Error	Barriers and Controls	S	D	L	RPN	Recommended Actions
4	Test Article Data									
4.1	Manufacturer data	Failure to secure information for review and verification with oxygen requirements	Information unavailable, delayed, or incomplete	Unknown history, characteristics, or condition of test article	Information required per NSS 1740.15	3	10	10	300	Assign responsibility for securing and providing necessary information. Include test procedure steps (Preoperation Setup Instructions) to verify information obtained and validated
4.2	Material certifications for LOX compatibility	Failure to secure information for review and verification with oxygen requirements	Information unavailable, delayed, or incomplete	Unknown history or characteristics of test article; application incompatibility; test delay; mishap	Information required per NSS 1740.15	3	10	10	300	Assign responsibility for securing and providing necessary information. Include test procedure steps (Preoperation Setup Instructions) to verify information obtained and validated
4.3	Pump and motor certifications	Failure to secure information for review and verification with oxygen requirements	Information unavailable, delayed, or incomplete	Unknown history or characteristics of test article; application incompatibility; test delay; mishap	Information required per NSS 1740.15	3	10	10	300	Assign responsibility for securing and providing necessary information. Include test procedure steps (Preoperation Setup Instructions) to verify information obtained and validated
4.4	Cleaning records	Failure to secure information for review and verification with oxygen requirements	Information unavailable, delayed, or incomplete	Unknown condition of test article; test delay; mishap	Information required per NSS 1740.15	8	5	5	200	Assign responsibility for securing and providing necessary information. Include test procedure steps (Preoperation Setup Instructions) to verify information obtained and validated

	Requirement	Potential Human Error	Performance-Shaping Factor	Potential Effects of Error	Barriers and Controls	S	D	L	RPN	Recommended Actions
5	Instrumentation									
5.1	Calibrated equipment	Use of improper equipment	Requirements not defined, documented, or verified	Equipment out of tolerance; unknown system conditions; unverifiable data; incorrect data; test invalidation	Clear requirements; coordination meetings; test documentation defining requirements; conduct detailed Requirements Reviews	10	1	2	20	Provide list of all transducers and test equipment with ranges, calibration curves, locations, and calibration dates
5.2	Instrumentation and calibration documentation	LTA documentation; incorrect or out-of-date documentation	Requirements not documented	Invalid installation and set up	Clear requirements; coordination meetings; test documentation defining requirements; conduct detailed Requirements Reviews	10	5	3	150	Document requirements in work instructions; distribute documentation; master copy on site
5.3	Define requirements	Instrumentation set up incorrectly; lack of proper instrumentation	Requirements not defined	Activation delay; test delay; insufficient data collection	Conduct detailed Requirements Reviews	10	5	3	150	Clearly define requirements; ensure understanding

	Requirement	Potential Human Error	Performance-Shaping Factor	Potential Effects of Error	Barriers and Controls	S	D	L	RPN	Recommended Actions
5.4	Permanent vs. test-specific equipment and instrumentation	Overlook requirements	Responsibilities not delineated; incorrect assumptions regarding existing instrumentation	Missed data collection; test delay	Configuration control; Master copy of instrumentation and equipment	5	5	2	50	Clarify difference; delineate responsibilities for operations and calibrated equipment
5.5	Availability of necessary sensors and equipment	Unapproved substitution	Schedule pressures; parts availability; inadequate planning	Out-of-range equipment or sensor used; data collection problems; test invalidation	Conduct detailed Requirements Review; configuration control; test constraints	10	2	2	40	Provide list of all transducers and test equipment with locations and calibration dates; expedite missing items
5.6	Sufficient prep time in schedule	Incomplete or partial preparation	Time constraints	Test delay; reduced capability	Requirements Review; schedule review and inputs	5	9	9	405	Coordinate with instrumentation and determine amount of time required
6	Voice Communication System									
6.1	Voice communication	Incorrect channel setting	Unfamiliar with system; channel indicators unavailable	No communication; miscommunication	Assignment of operations channel and work channel; call to stations; pretest briefings	9	3	3	81	Adequate documentation; emphasize communication requirements and importance in pretest briefings

	Requirement	Potential Human Error	Performance-Shaping Factor	Potential Effects of Error	Barriers and Controls	S	D	L	RPN	Recommended Actions
6.2	Call signs	Misunderstood instructions; missed instructions	New and non-standard; multiple users on individual call sign	No communication; miscommunication	Call to stations; pretest briefings	9	3	3	81	In pretest briefings, establish understanding of communication guidelines
6.3	Reliable equipment	Misunderstood instructions; missed instructions	Defective equipment; static or other noise on channel	No communication; miscommunication	Reliable system design to ensure communication	10	2	2	40	Pretest checkout of communication system on separate work instructions; preventive maintenance

S = Severity

D = Detection

L = Likelihood

RPN = Risk Priority Number (SxDxL)

LTA = Less than adequate